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Institute for Manufacturing and Sustainment Technologies

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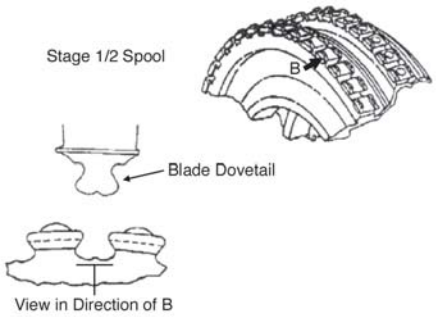
QUARTERLY

2004 No.1

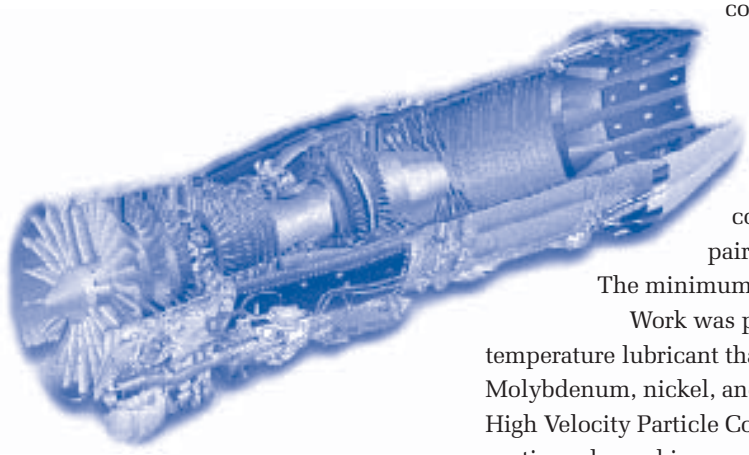
Engine Fretting Evaluation Continues

Current manufacturing methods for the F404 titanium compressor and titanium fan sections do not address resistance to fretting at the blade/disk interface (dovetail). The diagram at left shows the area of challenge.



Fretting is a wear phenomenon that involves the formation of oxide particles between wearing pairs coupled with small amplitude vibrations. The result is material pitting (fretting scars) on both surfaces of the dovetail. In the case of the F404 engine, fretting damage is caused by the inherent vibratory loading at the interface between the dovetail portion of the titanium disk and titanium blade. Following fretting, cracks are generated on the stick-slip boundary of the fretting scars. Low cycle fatigue cracks driven by the vibration and the additional stresses caused by frequent throttle movement could eventually cause a catastrophic material failure at either the compressor blade root or compressor disk.

Currently, a plasma spray technique is used to apply a copper-nickel-indium (CuNiIn) coating in the keyway at the disk/blade interface to separate the titanium/titanium wearing pairs at the dovetail. It has been determined that a better coating is desirable. Additionally, a solid lubricant Molydag 254 is brushed into the surface porosity of the copper-nickel-indium coating. Flight testing results indicate the coating can delaminate and extrude after approximately 2000 hours of engine operation. This affects the third stage compressor section leading to a number of blades replacements. Once a coating has extruded, a deleterious titanium/titanium wearing pair is created. Fretting damage as evidenced by pitting ensues. The minimum desired lifetime of the coating is 4000 hours of flight time.



Work was performed to find a replacement coating and high temperature lubricant that would meet the desired coating lifetime requirements. Molybdenum, nickel, and cobalt coatings were applied using both plasma spray and High Velocity Particle Consolidation (also known as cold spray). In lab tests, all three coatings showed improvement over the CuNiIn coating. In additional a solid boron-nitride lubricate was also identified. Four sets of three blades each of the following were coated using plasma spray for an Accelerated Simulated Mission Endurance Test.

- Mo coated blades with Boron-nitride
- Ni coated blades with Boron-nitride
- CuNiIn coated blades with Boron-nitride
- CuNiIn coated blades with Moly-dag

Initial engine test results indicate that the Mo and the Ni coated blades had improved performance compared to the CuNiIn blades. Evaluation continues.

For more information about this project contact Dr. Tim Eden at (814) 865-5880, or <tje1@psu.edu> by e-mail.

Focus On Repair Technology

Report Documentation Page

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IN THIS QUARTERLY

DIRECTOR'S CORNER

Projects in Full Swing

Fiscal year 2004 projects are in full swing, with several proposals for new starts under review. While funding was late to arrive, work was not delayed. As we resolve this fiscal year's issues, we must investigate potential projects for fiscal year 2005. I must emphasize the need to be ready to start projects as close as possible to October 1st. Again, we are concentrating on issues associated with the next generation carrier.

The featured article focuses on efforts to reduce the noise at the operators on the Marine Corps Mobile Electronic Warfare Support System, an advanced electronic system installed in the Light Armored Vehicle (LAV). The Applied Research Laboratory (ARL) has a LAV as a result of a REPTECH project focused on weld repair of cracks in the body structure. Two other projects have taken advantage of the vehicle's presence. ARL has an impressive expertise in the area of acoustics and hosts an interdiscplinary graduate degree for Penn State. Typically, solutions involve advanced materials, improved manufacturing processes and a reduction in life cycle costs, while improving the operator's environment and reducing detectability. Often projects at ARL involve several disciplines, and a system approach is a must. I believe this is one of ARL's strongest competencies.

There are many demands on the federal budget. The importance of reducing the cost of manufacturing critical acquisition systems should not be understated. The Manufacturing Technology (ManTech) Program concentrates on improving manufacturing processes to achieve efficiencies. The Navy manages the Manufacturing Technology Program through the use of Centers of Excellence. As a Navy Center of Excellence, iMAST works with program offices to identify requirements, and strives to couple technology with the targeted manufacturing process, working with the manufacturer, to reduce costs. The ManTech program invests research and development funding to mature technology to the point that the manufacturer can adopt it and the program office can certify it. Since this program focuses on near term implementation, most projects should complete in less than four years. If you have a manufacturing process in need of a solution, contact us for possible solutions!

Bob Cook

PENNSTATE iMAST

- MATERIALS PROCESSING TECHNOLOGIES
- MECHANICAL DRIVE TRANSMISSION TECHNOLOGIES
- LASER PROCESSING TECHNOLOGIES
- COMPLEX SYSTEMS MONITORING TECHNOLOGIES
- ADVANCED COMPOSITES MATERIALS TECHNOLOGIES
- NAVY/MARINE CORPS REPAIR TECHNOLOGIES
- MANUFACTURING SYSTEMS TECHNOLOGIES

Focus on Repair Technology

Light Armored Vehicle Noise Control

by Tim Brungart, Ph.D.

Exploiting the acoustics expertise resident at ARL Penn State, engineers were asked by the Marine Corps to address noise issues related to the Light Armored Vehicle. The integration of advanced materials, manufacturing processes, health monitoring, and acoustic tailoring promotes reductions in gross weight, vibration, interior noise, and life-cycle cost, as well as increases in mission range, survivability, and operational availability. The cost of these improvements are made more affordable due to large reductions in labor and operating and support (O&S) costs. iMAST's Navy ManTech program is focused to support the technical challenges facing Navy and Marine Corps ground combat and combat service support vehicles. To that end, a vehicle technology group is in place to address issues within operating and garrisoned forces. The following article addresses work conducted recently by ARL Penn State engineers on behalf of the U.S. Marine Corps.

The Mobile Electronic Warfare Support System Product Improvement Program (MEWSS PIP) integrated an advanced electronic warfare suite into a light armored vehicle identical to ARL's in-house LAV-25 Generation I, Figure 1. The mission of the MEWSS PIP vehicle is to intercept, identify, locate, and exploit modern threat radio communications and battlefield radars, as well as to disrupt or deny the threat's use of the electromagnetic spectrum. Typical missions are of sixteen (16) hours duration; the bulk of the time spent with the vehicle stationary and exercising its electronic warfare capabilities.

Marine Corps LAV on loan to ARL Penn State undergoing evaluation

Initial production MEWSS PIP vehicles, operating stationary with their engines at high idle and in their electronic warfighting mode, suffered from excessive interior sound levels. The sound levels were sufficiently high to warrant concern of potential hearing damage to the crew, even when equipped with noise reducing headsets. Other operational concerns associated with the high noise levels included speech intelligibility and psychological effects on the crew such as stress, lack of concentration, mental fatigue, anxiety, etc. In order to address these concerns, sound pressure levels were measured throughout the vehicle, with the vehicle operating in a variety of configurations, to identify the dominant noise sources and to develop corrective noise control treatments. In particular, the goal was to reduce, as much as possible, the overall A-weighted sound pressure levels (OASPLs) measured at crew locations, with as little effect on vehicle operation as possible. However, in order to meet strict production schedules and due to the limited availability of funds, the noise control treatments were also required to be quick, easy and relatively inexpensive to implement.

Acoustic Characterization of the MEWSS PIP Vehicle and Noise Control Treatments

In order to identify and rank-order the contributors to the noise levels measured at the five crew locations shown in Figure 2, the vehicle was run in six configurations and the OASPLs measured at each crew location for each configuration tested is shown in Figure 3.

Sound pressure levels up to 110 dB, levels typically associated with thunder and artillery fire, were measured inside the MEWSS PIP vehicle. With the exception of the noise at the Driver location, the noise throughout the vehicle was dominated by the evaporator fans in the air conditioning systems (ACS). At the crew locations in closest proximity to

PROFILE

Tim Brungart is a senior research associate at the Pennsylvania State University's Applied Research Laboratory and an associate professor of acoustics in Penn State's College of Engineering. He received B.S., M.S. and Ph.D. degrees respectively in aerospace engineering, mechanical engineering, and acoustics from The Pennsylvania State University. His research over the past 18 years has focused on noise and flow control which has resulted in improvements in the stealth of undersea weapons and improvements in the acoustic and aerodynamic performance of vacuum cleaners, automotive alternators and light armored vehicles. Dr. Brungart has also developed self-noise control techniques for high speed supercavitating vehicles, and contributed to fundamental knowledge through the development of scaling relationships for flow noise.

Dr. Brungart can be reached at (814) 863-3034 or by e-mail at <tab@wt.arl.psu.edu>.

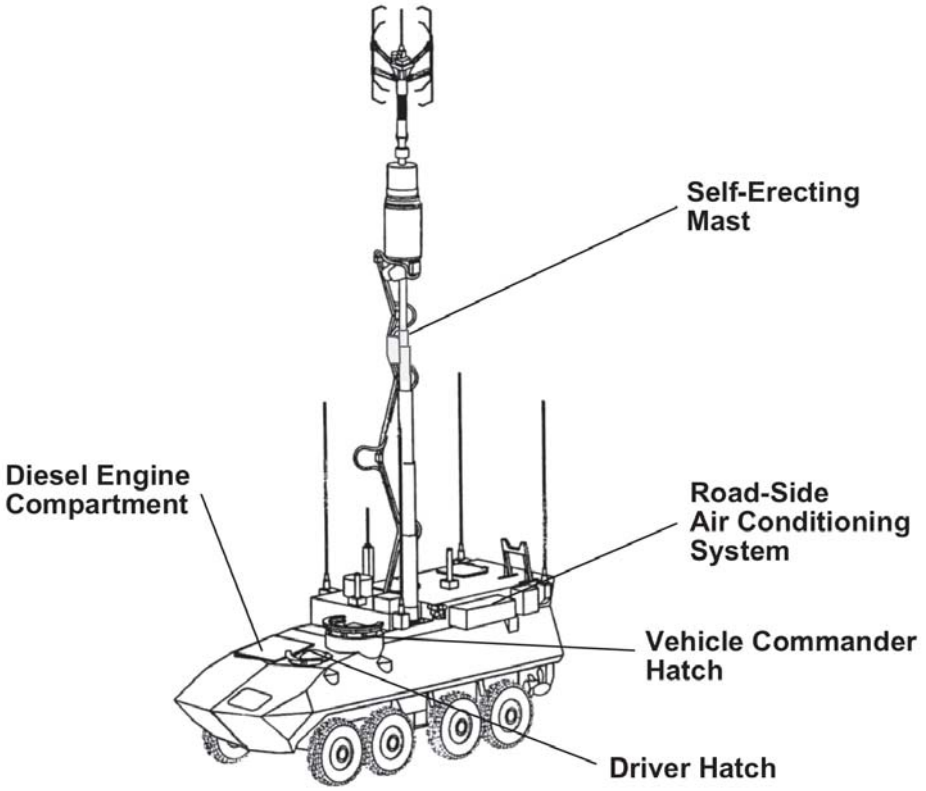


Figure 1. Exterior schematic of the Mobile Electronic Warfare Support System Product Improvement Program (MEWSS PIP) vehicle

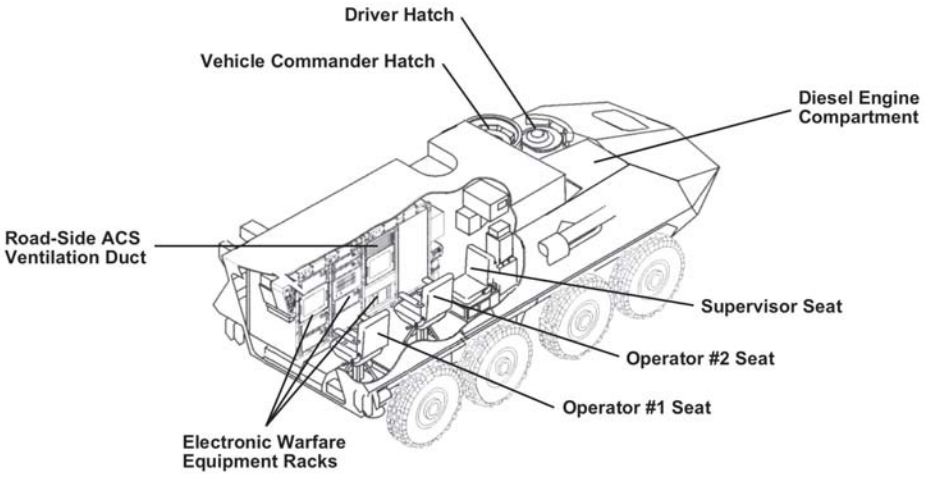


Figure 2. Exterior/interior schematic of the Mobile Electronic Warfare Support System Product Improvement Program (MEWSS PIP) vehicle

the ACS, Operators #1 and #2, the noise from the evaporator fans was approximately 20 dB greater in than the noise from the next most dominant source. Our noise control efforts focused on reducing the evaporator fan source level through the use of quiet replacement fans and on controlling the noise transmission paths from the fans to the various crew locations with a lined plenum attenuator on the curb-side ACS and ventilation duct silencing treatments on the road-side ACS.

Replacement evaporator fans were identified that met all system aerodynamic requirements yet offered a 14 dB reduction in radiated sound power, measured under laboratory conditions, compared to the baseline fans. The original plenum that fit over the curb-side ACS evaporator fans was replaced with a lined plenum attenuator with sound absorbing passages that were designed to attenuate the fan noise up to 19 dB while increasing the system backpressure by less than 20%, thereby having little effect on the ACS cooling capacity. Likewise, silencing treatments were designed into the road-side ACS ductwork to reduce the noise from the fan up to 12 dB in level yet have no effect on the ACS cooling capability. Laboratory measurements and measurements performed in the MEWSS PIP vehicle indicated that these design goals were achieved.

Results

The MEWSS PIP vehicle was again run in the six configurations identified in Figure 3 and OASPLs were measured at each crew location with each noise control treatment installed in the vehicle. The results are shown in Figure 4. The combined noise control treatments reduced the A-weighted sound levels 15 dB at the Operator #1 location, 18 dB at the Operator #2 location, 11 dB at the Supervisor location, and 7 dB at the Commander location. An 18 dB reduction in sound pressure corresponds to a 98.5% reduction in acoustical energy! No reduction was achieved at the Driver location due to the dominance of

engine-related noise.

The quiet replacement evaporator fans reduced the measured OASPLs by 6 dB at most. This is much less than the 14 dB reduction measured under laboratory conditions. We attribute the reduced noise control effectiveness of the quiet replacement fans in the MEWSS PIP vehicle, compared to the laboratory measurements, to the increased sensitivity of the replacement fans to inflow distortions caused by the circuitous flow path in the vehicle's ACS. The curb-side ACS lined plenum attenuator, with the quiet replacement evaporator fans installed, was most effective at the Operator #1 location, reducing the levels measured there by an additional 8 dB. The road-side ACS ventilation duct silencing treatments reduced the OASPL measured at the Operator #2 location an additional 8 dB over the levels measured with the quiet ventilation fans and curb-side lined plenum attenuator installed.

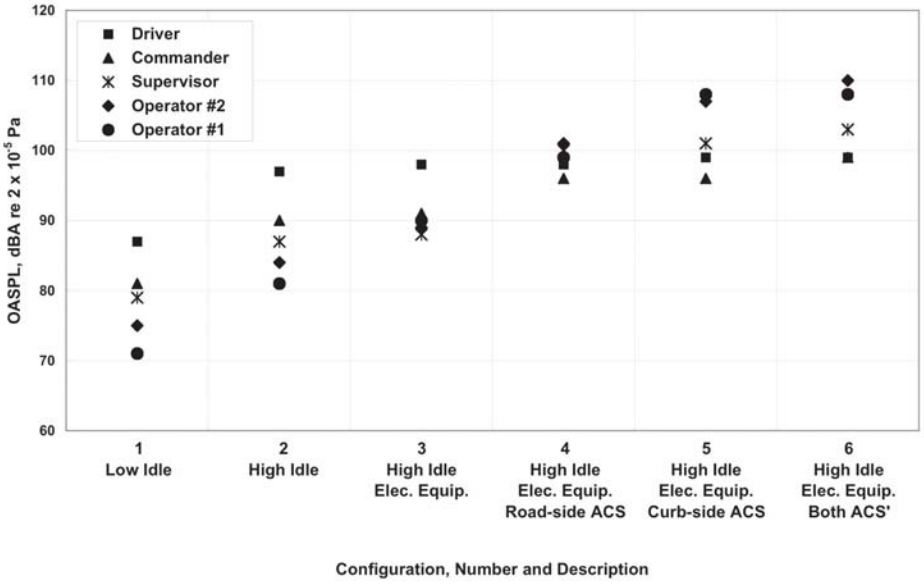


Figure 3. Overall A-weighted sound pressure levels measured at the five crew locations for the six vehicle operating configurations

Summary

Air conditioning system evaporator fans were identified as the dominant sources of noise in an LAV modified to conduct electronic warfare operations. The fan source levels were reduced by replacing the baseline fans with quiet replacement units that met all system aerodynamic requirements. The airborne noise transmission paths from the evaporator fans to the crew locations were controlled with a lined plenum attenuator and ventilation duct silencing treatments. These simple, cost-effective treatments reduced the interior A-weighted sound levels from 110 dB to 92 dB and had no effect on vehicle operation.

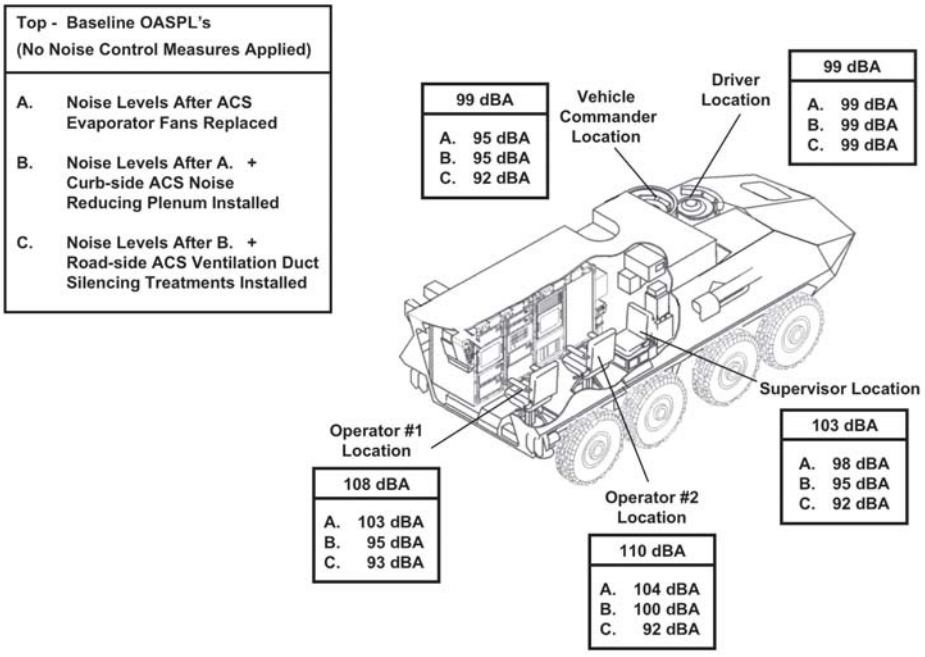


Figure 4. Measured overall A-weighted sound pressure levels at the five crew locations for each of the three noise control treatments incorporated into the MEWSS PIP vehicle

Acknowledgement

This work was sponsored by the U.S. Marine Corps Systems Command, and monitored by Major Leslie M. Prior. Their support is gratefully acknowledged. The contributions of Mr. Steven D. Young, Lockheed Martin Systems Integration Owego, and Colonel Andrew F. Mazzara USMC (retired) in various aspects of this work are acknowledged as well.

Vehicle Technology Efforts at ARL Penn State

As noted in our feature article, ARL Penn State has addressed, and continues to address, issues related to ground combat and combat service support vehicles. To that end, a vehicle technology focus group was established several years ago to exploit the resident expertise and facilities available at Penn State which can support both the Navy and the Marine Corps ground vehicle platforms. The following graph depicts some of the technology areas being applied to various system platforms. Additionally, affiliations with Gear Research Institute, Pennsylvania Transportation Institute, Penn State Center for Supply Chain Research, USMC Maintenance Directorate, ASME, and TACOM enable ARL and iMAST to focus on current challenges facing the fleet, and beyond.

Drive System Technologies

- Advanced gear and bearing steels
- Laser fabricated (cut and welded) housings
- Laser probe workpiece positioning
- Ausform finished gears and bearings
- Intelligent noncontact measurement of spiral bevel and face gears
- Gear noise control
- Design for power density

Health Usage Monitoring System Technologies

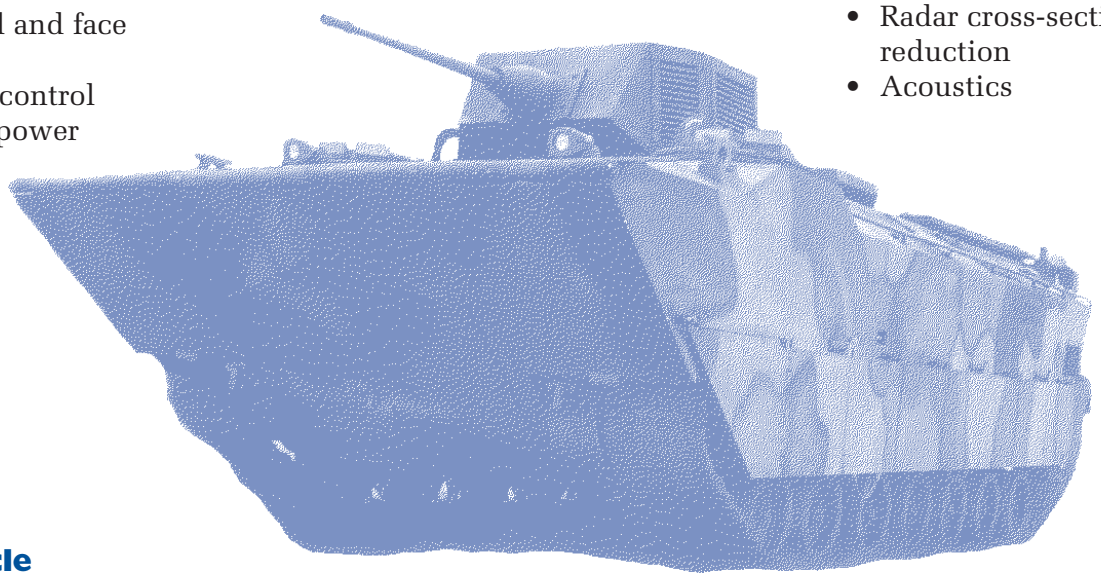
- Condition-Based Maintenance
- Distributed diagnostic system architectures
- Embedded engine predictive diagnostics
- Maintenance Management Information for troubleshooting and diagnosis

Chemical-Biological-Radiological Technologies

- Photon-based cleaning of CBR agents
- Laser-based cleaning of CBR agents

Signature Reduction Technologies

- Composite thermal tiles
- Radar cross-section reduction
- Acoustics



Track Vehicle System Technologies

- Lightweight HS materials
- Laser cladding and heat treating

Structural System Technologies

- Armor systems
- Materials and design

Powertrain Technologies

- Performance prediction
- Rapid prototyping
- Drive shaft laser balancing
- Condition monitoring
- Wear-resistant coatings via cold gas dynamic spraying and Electron Beam-Physical Vapor Deposition
- Spray formed High Temperature aluminum alloys
- Localized laser HT and cladding for wear and corrosion resistance

Repair Technology

- Non-Destructive Inspection technologies (shearography)
- Coating application and removal
- Component repair methods (laser cladding)

Drivetrain Center's Neal Recognized

Associate research engineer Gary Neal, of ARL's Drivetrain Technology Center, was recognized twice by Lockheed Martin for his design excellence and leadership within Penn State's Learning Factory, a university-industry partnership established to help industrial clients, while enhancing engineering education at Penn State. The program was developed in order to integrate design, manufacturing, and business realities into Penn State's engineering curriculum. In addition to the personal recognition received by Mr. Neal, Penn State's Learning Factory was also cited as an Exemplary Effort by the Corporation and Foundation Alliance (CFA), a program recognition effort sponsored by the National Science Foundation. CFA is committed to nurturing the evolution of high-quality undergraduate science, mathematics, engineering and manufacturing technology. The Alliance consists of 39 corporations and foundations including: Boeing, DuPont, HP, IBM, Lockheed Martin, Lucent, Microsoft, NSF, Packard Foundation, Sloan Foundation, and the SME. We are proud of Gary Neal's accomplishment and look forward to his continued success within the Drivetrain Technology Center, and beyond.

Congressman Bill Shuster (center) discusses gear technology development at ARL Penn State with ARL's Suren Rao. Dr. Tom Donnellan (left), ARL associate director for materials and manufacturing, and Dr. Ed Liszka (right), director of ARL Penn State look on.

Congressman Shuster Visits iMAST

Congressman Bill Shuster (R. PA 9th District) recently visited ARL Penn State where he was briefed on iMAST's Navy ManTech Program. Congressman Shuster was able to examine first hand many of the projects iMAST has underway in support of the Navy and the Marine Corps. In concert with Navy ManTech objectives, the congressman was educated on the various technologies being worked on and how they impact fleet readiness. Congressman Shuster was further briefed on how technologies developed under the Navy ManTech program can enhance economic development, once the technologies have been transitioned to the commercial sector.

Center director, Bob Cook, talks with visitor at iMAST exhibit booth during DMC 2003 conference in Washington, D.C.

iMAST Participates in DMC

Members of iMAST recently participated in the annual Defense Manufacturing Conference, held in Washington, D.C.. Once again leaders from government, industry and academia assembled to exchange perspectives and information relative to manufacturing technology and industrial modernization. This year's theme, "Transitioning Affordable Combat Power to Air Warfighters" set the stage for forum discussions concerning the defense industrial base and its impact on the future of air power. Hosted by the U.S. Air Force, the conference featured speakers like Ms. Susanne Patrick, Deputy Under Secretary of Defense for Industrial Policy; the Honorable James G. Roche, Secretary of the Air Force; and Congressman David Hobson of Ohio. iMAST's Dr. Bill Mark participated in the poster session with a presentation titled: "Gear Metrology and Performance Prediction: Reduction of Gear-Generated Internal and Radiated Noise of Combat Ships." Next year's annual conference will be held in Las Vegas, Nevada from 29 November to 2 December 2004.

DDR&E Recognizes Swanson

Mr. Paul Swanson, a reasearch associate at Penn State's Applied Research Laboratory, and Navy ManTech project leader, was recognized for his polycan fabrication improvement project work. John Todaro, Director of the Office of Technology Transition, Office of the Director of Defense Research and Engineering, recently commended Mr. Swanson for work that has "...a significant positive impact on future production of our weapon systems." ARL Penn State and iMAST take great pride in its supporting relationship with the U.S. Navy, Marine Corps, and the Department of Defense.

CALENDAR OF EVENTS

3–6 Aug.	ONR Naval-Industry R&D Conference	★★★★★★★ *visit the iMAST booth*	Washington, D.C.
2–6 Aug.	TechTrends 2004	★★★★★★★ *visit the iMAST booth*	Pittsburgh, PA
16–20 Aug.	Penn State Rotary Wing Short Course: Comprehensive Rotary Wing Technology		State College, PA
18–20 Aug.	ARMTech	★★★★★★★ *visit the iMAST booth*	Kittanning, PA
7–9 Sep.	Combat Vehicles Conference		Fort Knox, KY
16–17 Sep.	NSRP Sub-panel Committee Meeting		State College, PA
Sep. TBA	Marine Corps League Expo	★★★★★★★ *visit the iMAST booth*	Quantico, VA
Sep. TBA	Marine Corps Systems Command Industry Day		Crystal City, VA
26–28 Oct.	AGMA Fall Technical Meeting		Milwaukee, WI
Oct. TBA	Expeditionary Warfare Conference		Panama City, FL
Oct. TBA	AUSA Expo		Washington, D.C.
Oct. TBA	DoD Maintenance Conference		TBA
17–18 Nov.	Materials & Manufacturing Advisory Board Meeting (focus: Maritime Technologies & Seabasing)		State College, PA
2005			
23–24 May	Johnstown Showcase of Commerce	★★★★★★★ *visit the iMAST booth*	Johnstown, PA
1–3 Jun.	American Helicopter Society Forum 61	★★★★★★★ *visit the iMAST booth*	Grapevine, TX
16–19 Oct.	AGMA Gear Expo 2005		Detroit, MI

Quotable

"We will spend whatever it takes to equip and enable our sailors, but we do not want to spend one extra penny for manpower we don't need."
—Admiral Vern Clark, Chief of Naval Operations

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